5.3 EARTHQUAKES

A major earthquake hazard event has been determined to have a **Low** likelihood of occurrence in Benton County within the five-year planning cycle of this Plan. Therefore, although some hazard characterization information is presented below, no further risk assessment has been performed for earthquake hazards. Additional analyses to further characterize the risks of this hazard and the development of suitable mitigation action items will be conducted in the future based on periodic reviews of this hazard mitigation plan and available resources

5.3.1 Nature of the Hazard

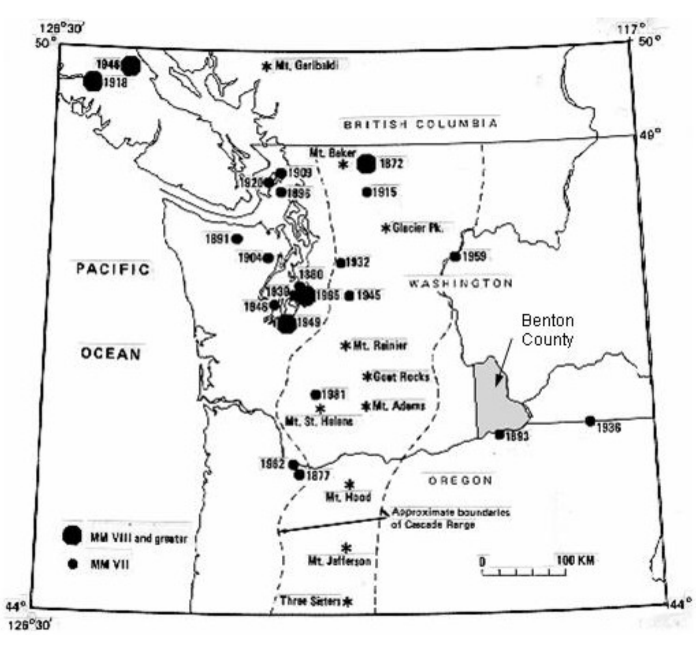
The Pacific Northwest Seismograph Network records roughly 1,000 earthquakes per year in Washington and Oregon. Between one and two dozen of these cause enough ground shaking to be felt by residents. Most are in the Puget Sound region, and few cause any damage.

Historical Events

Ground shaking from historic earthquakes in Washington and the western U.S. has been noted in Benton County, and has resulted in only minor damage in several events. Figure 5.3-1 shows a map of the largest earthquakes in the Pacific Northwest from 1872-1987 and Table 5.3-1 provides a summary of past earthquakes and their effects in Benton County. Table 5.3-2 provides a comparison between earthquake magnitude and intensity.

Earthquake magnitude is determined from measurements recorded by seismographs or is estimated for pre-instrumental earthquakes based on felt area. Intensity measures the strength of the shaking produced by the earthquake at a certain location and is determined from effects on people, human structures, and the natural environment.

Figure 5.3-1. Largest Pacific Northwest Earthquakes, 1872-1987



Source: After Nosan and others (1988)

The Pacific Northwest Seismograph Network (PNSN) has operated seismograph stations and located earthquakes in Washington and Oregon since about 1969. A search of the PNSN earthquake catalog shows that between 1969 and July 2003 there were over 260 mostly shallow crustal earthquakes with epicenters in or near Benton County. The two largest earthquakes were on October 25, 1971 (3.8M) near the northern tip of the county and on June 28, 1975 (3.8M) about 8 miles south-southeast of Prosser beneath the Horse Heaven Plateau. The vast majority of these earthquakes had magnitudes between 2.0-3.0 and were too small to produce any damage or be felt by local residences.

Table 5.3-1. Historic Earthquakes and Their Effect in Benton County

Date	Location	Size	Effect in Benton County
1872, Dec. 14	North Cascades, WA	MMI IX, 7.3M	MMI IV-VI
1893, Mar. 7	Umatilla, OR	MMI VII, 4.7M	Estimated MMI I-VI
1936, Jul. 15	Milton-Freewater, OR	MMI VII, 5.75M	MMI III-V
1939, Nov. 12	S. of Olympia, WA	MMI VII, 5.75M	MMI I-IV
1943, Apr. 24	Near Chelan, WA	MMI V	MMI I-IV
1945, Apr. 29	Stampede Pass, WA	MMI VII, 5.5M	MMI I-IV
1946, Feb 14	Puget Sound, WA	MMI VII, 6.3M	MMI I-III
1949, Apr. 13	Puget Sound, WA	MMI VIII, 7.1M	MMI I-IV
1959, Aug. 5	Near Chelan, WA	MMI VI-VII, 5.0M	MMI I-IV
1959, Aug. 17	Hebgen Lake, MT	MMI X, 7.5M	MMI I-IV
1965, Apr. 29	Puget Sound, WA	MMI VIII, 6.5M	MMI I-IV
1983, Oct. 28	Borah Peak, ID	MMI VII, 7.3M	MMI II-IV
2001, Feb 28	Near Olympia, WA	MMI VIII, 6.8M	MMI II-III, minor damage to ten private residences

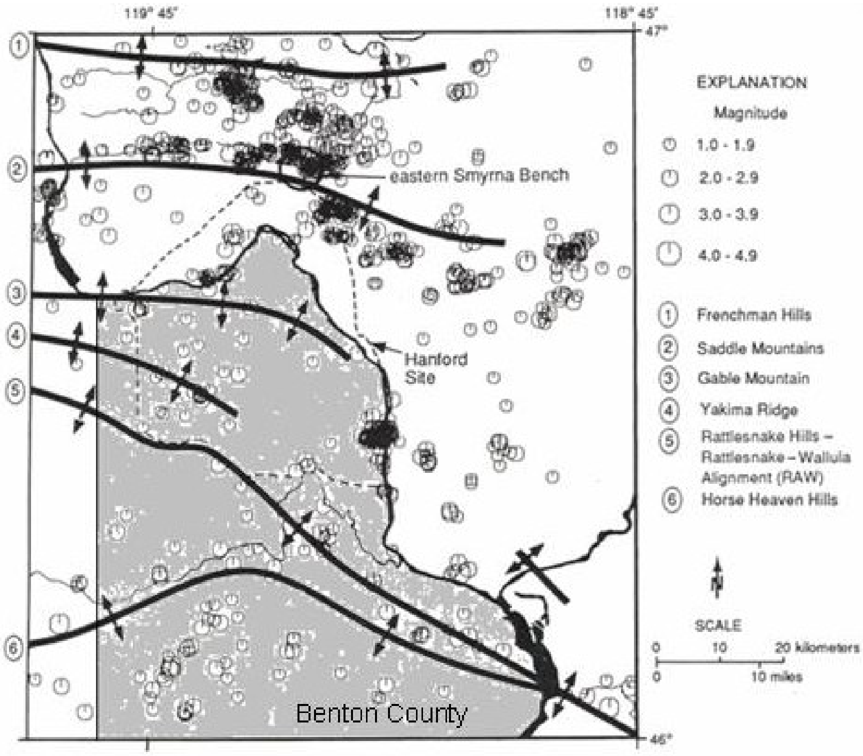
Earthquake size and effect based on the Modified Mercalli Intensity (MMI) scale and estimated or measured magnitude (M), see Table 5.3-2 for explanation. Sources: McCrumb and others (1989), Nosan and others (1988), Washington Public Power Supply System (1981), USGS Earthquake Hazards Program and the Pacific Northwest Seismograph Network.

Table 5.3-2. Earthquake Magnitude and Intensity Comparison

Magnitude	MMI Intensity	Description
1.0-3.0	I	**I.** Not felt except by a very few under especially favorable conditions.
3.0-3.9	II-III	**II**. Felt only by a few persons at rest, especially on upper floors of buildings. **III**. Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
4.0-4.9	IV-V	**IV**. Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably. **V**. Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
5.0-5.9	VI-VII	**VI**. Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight. **VII**. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
6.0-6.9	VII-IX	**VIII**. Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. **IX**. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
7.0 and higher	VIII or higher	**X**. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent. **XI**. Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly. **XII**. Damage total. Lines of sight and level are distorted. Objects thrown into the air.

Source: USGS Earthquake Hazards Program

Figure 5.3-2. Earthquakes recorded March 1969 to January 1989 and Yakima Fold Belt anticlines and faults



Source: Modified from Reidel and others (1994)

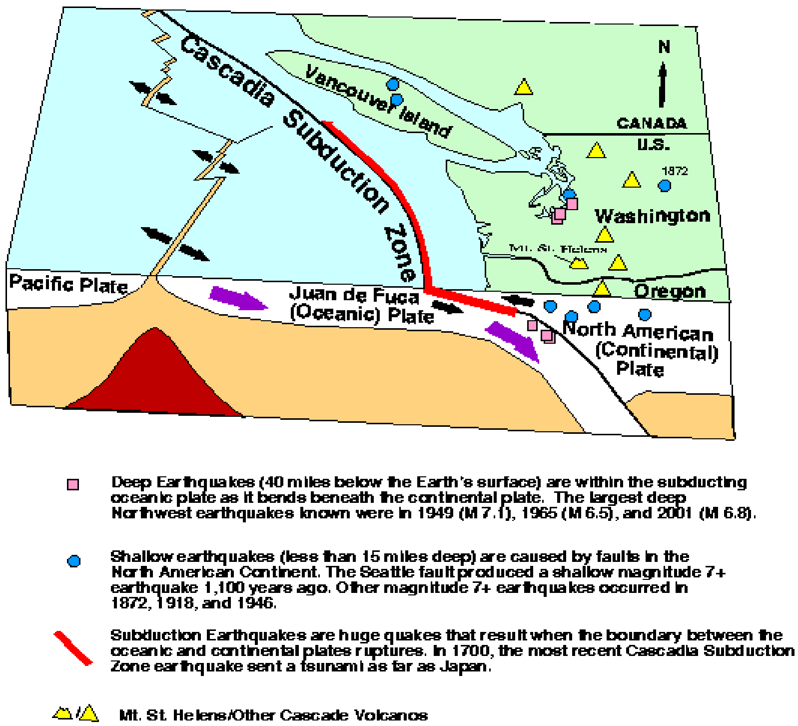
Benton County is located near the eastern margin of the Yakima Fold Belt (Figure 5.3-2). The Yakima Fold Belt is composed of complex anticlines that generally trend northwest, east-west, to northeast and typically have imbricated thrust or reverse faults along their northern limbs. Local earthquakes are generally not associated with known faults except on the north side of the Saddle Mountains, north of Benton County (Figure 5.3-2). However, geologic evidence of young faulting has been found on the Saddle Mountains, on Gable Mountain, and in the Wallula Gap area along the Rattlesnake-Wallula alignment (RAW; Reidel and others, 1994). Faults along the Saddle Mountains, the RAW, and the northwest-trending portion of the Horse Heaven Hills are some of the major faults in eastern Washington that are considered in the evaluation of future seismic hazards in this area (Frankel and others, 2002).

Earthquake Characteristics

Earthquakes are the result of geologic processes producing stresses in the earth. In the Pacific Northwest, oceanic crust is being pushed beneath the North American continent along a major boundary parallel to the coast of Washington and Oregon. The boundary called the "Cascadia Subduction Zone" lies about 50 miles offshore and extends from the middle of Vancouver Island in British Columbia past Washington and Oregon to northern California (Figure 5.3-3). The interaction of these two “plates” produces three primary types of earthquakes:

Deep (Intraplate) Earthquakes: The three most recent damaging earthquakes in Washington, in 2001 (magnitude 6.8, near Olympia), 1965 (magnitude 6.5, located between Seattle and Tacoma), and in 1949 (magnitude 7.1, near Olympia), were roughly 40 miles deep and were in the oceanic plate where it lies beneath the continent. Each earthquake caused serious damage in the Puget Sound area, and was felt as far away as Montana.

Figure 5.3-3. Pacific Northwest Earthquake Model



Source: The Pacific Northwest Seismograph Network

Shallow crustal earthquakes: The largest historic earthquake in Washington occurred in 1872 in the North Cascades. This earthquake had an estimated magnitude of 7.3 and was followed by many aftershocks. It was probably at a depth of 10 miles or less within the continental crust.

Subduction Zone earthquakes: Although no large earthquakes have happened along the offshore Cascadia Subduction Zone since historic records began in 1790, similar subduction zones worldwide do produce "great" earthquakes - magnitude 8 or larger. These occur because the oceanic crust "sticks" as it is being pushed beneath the continent, rather than sliding smoothly. Over hundreds of years, large stresses build which are released suddenly in great earthquakes. Such earthquakes typically have a minute or more of strong ground shaking, and are followed by numerous large aftershocks. The Alaskan earthquake of 1964 was a great subduction zone earthquake. Geologic evidence shows that the Cascadia Subduction Zone has also generated great earthquakes, and that the most recent one was about 300 years ago.

Earthquake Related Hazards

The principal ways in which earthquakes cause damage are by strong ground shaking and by the secondary effects of ground failures (surface rupture, ground cracking, landslides, liquefaction, and subsidence). The severity of these hazards depends on several factors, including proximity to the earthquake, earthquake magnitude and depth, and soil and slope conditions.

Ground Shaking **-** Ground shaking is the motion felt on the earth's surface caused by seismic waves generated by the earthquake. It is the primary cause of earthquake damage. The strength of ground shaking (strong motion) depends on the magnitude of the earthquake, the type of fault, and distance from the epicenter (where the earthquake originates). Ground shaking generally decreases with distance from the earthquake source (attenuation), but locally can be much higher than adjacent areas, due to amplification (an increase in strength of shaking for some range of frequencies). Amplification occurs where earthquake waves pass from bedrock into softer geologic materials such as sediments. Buildings on poorly consolidated and thick soils will typically see more damage than buildings on consolidated soils and bedrock.

Ground Failures **-** Ground failures accompanying earthquakes include fault rupture (surface faulting), ground cracking, subsidence, liquefaction, and landslides.

- **Fault rupture** occurs as offsets of the ground surface and is limited to the immediate area of the fault. Other ground failures can occur over a wide area and can have several causes.
- **Earthquake-Induced Landslides** are secondary earthquake hazards that occur from ground shaking. They can destroy roads, buildings, utilities, and other critical facilities necessary to respond and recover from an earthquake.
- **Liquefaction** occurs when water-saturated sands, silts, or (less commonly) gravels are shaken so violently that the grains rearrange and the sediment loses strength, begins to flow out as sand boils (also called sand blows or volcanoes), or causes lateral spreading of overlying layers. Ground failures, such as ground cracking or lateral spreads (landslides on very shallow slopes) commonly occur above liquefied layers. The ground was badly cracked in the 1936 Milton-Freewater earthquake and noteworthy liquefaction took place in Puyallup during the 1949 earthquake.
- **Subsidence** (including differential ground settlement) can result in the flooding and (or) sedimentation of subsided areas.

5.3.2 Hazard Assessment

Hazard Identification

Benton County is likely to experience ground shaking from future earthquakes in the Pacific Northwest and western U.S. as it has in the past. A local shallow crustal earthquake (e.g. on the RAW or Horse Heaven Hills faults) similar to the July 15, 1936 Milton-Freewater earthquake (M=5.75) may even result in local ground failures. In the epicentral area of the 1936 earthquake ground failures included:

> "The ground was badly cracked and there were marked changes in the flow of well water…Four miles west of Freewater the ground was cracked over an area 1,200 to 1,500 ft long by 50 to 100 ft wide…crack some 200 or 300 ft long was from 1 to 6 ft wide…concrete pavements were cracked…cracks appeared in the ground ranging in size from less than pencil width to a 3-ft crack which was 8 ft deep…At a ranch between Umapine and Freewater, nine cracks appeared ranging up to 6 inches in width and water was forced out of the ground in a dozen places." (Neumann, 1938)

Local studies have not been completed to be able to define the location of specific future earthquake impacts within Benton County. The areas that are more likely to experience impacts from future local earthquakes are those areas closest to the faults associated with the Yakima Fold Belt (see Figure5.3-2).

Vulnerability Assessment

Benton County has been spared significant damage from the largest historic earthquakes in the Pacific Northwest (see Table 5.3-1). However, the RAW fault and the northwest-trending Horse Heaven Hills fault in the southeast part of the County (see Figure 5.3-2) are two of the major faults in eastern Washington that are considered in the evaluation of future seismic hazards in this area (Frankel and others, 2002). A moderate-size earthquake along these faults would be expected to produce damaging ground shaking and possibly local ground failures within the county.

The United States Geological Survey (USGS) through the National Earthquake Hazard Reduction Program (NEHRP) produces national maps of earthquake shaking hazards that provide information essential to creating and updating the seismic design provisions of building codes used in the United

States. The most recent USGS seismic hazard maps (Frankel and others, 2002) indicate that the peak ground acceleration expected in Benton County from future earthquakes with a 2% probability of exceedance in 50 years (i.e., a return period of about 2,500 years) is between 0.18g and less than 0.25g (i.e., about 18% to less than 25% of the force of gravity).

Since a complete vulnerability assessment has not been completed, it is not possible at this time to describe the types and number of existing and future buildings, infrastructure, and critical facilities that are located within potential earthquake hazard areas, nor to estimate the potential dollar losses to vulnerable structures. At risk of damage from future earthquakes are water, sewer, and natural gas pipelines, roads, power lines and infrastructure, buildings, and private property located within the county.

Risk Analysis

A risk analysis has not been completed at this time.

5.3.3 Community Issues

Current Conditions

Seismic hazards are not seen as a significant risk to development in Benton County (Benton County Comprehensive Plan, 1998).

Ongoing Mitigation

Benton County requires that design criteria from the 1997 Unified Building Code (UBC) be used for new buildings and structures within the county. The 1997 UBC places the county within Seismic Zone IIB which requires seismic design criteria of 0.20g peak ground acceleration plus site-specific response spectra.

5.3.4 Mitigation Strategy

Potential mitigation strategies include providing structural defenses for homes and other buildings to reduce the potential for damage to the structure and/or its contents. Examples include:

- Bracing cripple walls – A cripple wall is a short wall resting on the foundation and supporting the floor and exterior walls. Adding bracing to the cripple wall can reduce or prevent shifting during an earthquake. FEMA estimates that bracing a two-foot high cripple wall costs approximately $1.50 in materials per linear foot of wall. Labor, permits, and other costs are not included.

- Bolting sill plates to foundation – If the sill plate is not securely anchored to the foundation, an earthquake can cause it to shift. The stability of the structure can be increased by anchoring the sill plate to the foundation with bolts or alternative means. FEMA estimates that having a contractor bolt the sill plates to the foundation costs approximately $50 to $75 per bolt, with bolts placed every six linear feet.

- Flexible connections on gas and water lines – Rigid gas and water lines can be broken at the connection points during an earthquake. Installing flexible connection piping between appliances and their supply lines can reduce the potential for damage during small movements. It will not provide protection against extensive movements or if the appliance falls. Anchoring the appliance to the floor or wall provides additional protection.

- Securely mounting large mirrors and framed pictures.
- Securing drawers and cabinet doors with latches, bolts, safety hasps, or child-proof locks.
- Restrain desk-top computers and small appliances.
- Anchoring tall bookcases and file cabinets.
- Anchor and brace propane tanks and gas cylinders. FEMA estimates that bracing and anchoring a propane tank costs approximately $250, plus approximately $75 for flexible connections at the tank and in the structure.

5.3.5 Resources

State Resources

Washington State Military Department, Emergency Management Division
Earthquake Preparedness Program
Preparedness information for all types of disasters for family and community.

Programs Unit, Building 20, M/S: TA-20
Camp Murray, Washington 98430-5122
Phone: 800-562-6108
Phone: 253-512-7000
Fax: 253-512-7203

Washington State Department of Natural Resources
Data and applied geological and geo-technical services are available to the public, local governments, and universities about the geology of the state. Geologic maps, presentations, and publications.

Division of Geology and Earth Resources
PO Box 4707
1111 Washington Street SW
Olympia, Washington 98504-7007
Phone: 360-902-1450

University of Washington
Taped messages on current and historic seismicity. Maps, reports, and brochures, on earthquake faults in Washington.

Geophysics Program
Seismology Lab
PO Box 351650
Seattle, Washington 98195-1650
Hotline: 206-543-7010
Phone: 206-553-8349

Washington Division of Geology and Earth Resources website:
http://www.dnr.wa.gov/geology/hazards/equakes.htm

Pacific Northwest Seismograph Network
http://www.ess.washington.edu/SEIS/PNSN/welcome.html

Federal Resources

US Geological Survey
Maps and reports on earthquake faults in Washington. USGS has a new earthquake portal that will reach all US Geological Survey earthquake information, real-time and historic. USGS Earthquake Hazards Program website: http://earthquake.usgs.gov/
Box 351310, Geological Sciences
University of Washington
Seattle, WA 98195

Federal Emergency Management Agency, Region X (FEMA)
Federal Regional Center
130 228th Street, SW
Bothell, WA 98021-9796
Phone: 425-487-4604
Fax: 425-487-4622

U.S. Army Corps of Engineers
Emergency Management Branch
Seattle District
P.O. Box 3755 (OD-EM)
Seattle, WA 98124-2255
Phone: 206-764-3406
Fax: 206-764-3319
Email: david.n.spicer@usace.army.mil

Additional Resources

International Conference of Building Officials
Washington Chapter
PO Box 7310
Olympia, Washington 98507

Information on building design

Institute for Business and Home Safety
Information on preparing your home and business for natural disasters, to reduce loss when such an event occurs.
175 Federal Street
Suite 500
Boston, MA 02110-2222
Phone: 617-292-2003
Fax: 617-292-2022

Structural Engineers Association of Washington
Information on building design, and emergency preparedness
PO Box 72
Southworth, Washington 98386
Phone: 206-682-6026
Email: seaw@seaw.org

Western States Seismic Policy Council
Information at the national level on hazard reduction planning and policy.
125 California Avenue, Suite D201 #1
Palo Alto, CA 94306
Phone: 659-330-1101
Fax: 650-326-1769
Email: wsspc@wsspc.org

Other references and/or literature cited include:

Benton County Comprehensive Plan, June 22, 1998.

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